4-19-2016

Pathways from Education to Fertility Decline: A Multi-Site Comparative Study

Kristin Snopkowski
Boise State University

Mary C. Towner
Oklahoma State University

Mary K. Shenk
University of Missouri

Heidi Colleran
Toulouse School of Economics

This is an author-produced, peer-reviewed version of this article. The final, definitive version of this document can be found online at *Philosophical Transactions of the Royal Society B: Biological Sciences*, published by the Royal Society. Copyright restrictions may apply. doi: 10.1098/ rstb.2015.0156

***Phil. Trans. R. Soc. B.* article**

PHILOSOPHICAL TRANSACTIONS B

Phil. Trans. R. Soc. B.
doi:10.1098/rstb.2015.0156

Pathways from Education to Fertility Decline: A multi-site comparative study

Kristin Snopkowski*,[1], Mary C. Towner[2], Mary K. Shenk[3], Heidi Colleran[4]

[1]*Department of Anthropology, Boise State University, 1910 University Drive, Boise, ID 83725, USA*
[2]*Department of Integrative Biology, Oklahoma Stae University, Stillwater, OK 74078, USA*
[3]*Department of Anthropology, University of Missouri, Columbia, MO 65211 USA*
[4]*Institute for Advanced Study in Toulouse, Toulouse School of Economics, Toulouse 31015, France*

Keywords: fertility decline, education, demographic transition, mortality, social networks, contraception

Abstract

Women's education has emerged as a central predictor of fertility decline, but the multiple possible mechanisms by which education can affect fertility have not been subject to detailed comparative investigation across multiple sites. In this paper, we use structural equation modelling to examine potential pathways between education and fertility in three different geographic locations: Matlab, Bangladesh; San Borja, Bolivia; and rural Poland. Using a comparable set of variables we show that the pathways by which education affects fertility differ in important ways, yet also show key similarities. In particular, we find that across all three contexts, education affects age at first birth via women's work, but this pathway only influences fertility in rural Poland. In Matlab and San Borja, education is associated with lower local childhood mortality which influences the number of births, but this pathway is not important in rural Poland. The similarities across sites suggest that common elements are important in how education drives demographic transitions cross-culturally, but the differences suggest that local ecologies also play an important role in the relationship between education and fertility decline.

Main Text

Introduction

The Demographic Transition, a change from high mortality and fertility to low fertility and mortality, has now occurred throughout much of the world (1–4). While researchers generally agree on the reasons we see reductions in mortality, there remains significant debate on why fertility rates have declined. The dramatic reduction in fertility appears perplexing evolutionarily, particularly as people have access to more resources than ever before in developed economies (4–6). Additionally, high-status or wealthy individuals tend to be the first adopters of the low-fertility strategy in a fertility transition, which is the opposite of what is seen in traditional hunter-gatherer and horticultural societies where fertility is positively correlated with status (7,8). While many hypotheses about fertility decline have been developed and tested, very little work has focused on cross-cultural comparisons of the process or the mechanisms by which different predictors of fertility decline actually influence fertility outcomes.

*Author for correspondence (kristinsnopkowski@boisestate.edu).
†Present address: Department of Anthropology, Boise State University, 1910 University Drive, Boise, ID 83725

Here we take a broad biosocial approach drawing on both life history theory and cultural evolutionary theory to understand fertility decision-making. Life history theory seeks to understand how evolutionary forces shape organisms' life stages, such as growth, age at maturity, reproductive pace, clutch size, amount of parental investment, and senescence to optimize fitness. This body of theory provides predictions about how individuals face trade-offs in the allocation of resources to different productive and reproductive goals. One fundamental trade-off that all organisms face is whether to allocate energy towards the self, for example, by growing or investing in immune function, or towards reproduction, with the assumption that allocating energy towards oneself today should pay-off by increasing the probability of being able to produce successful offspring in the future (9,10). Cultural evolutionary theory, in contrast, seeks to understand how some beliefs and attitudes spread and persist, while others disappear, and how rules about learning evolved to enhance fitness scale up to produce group level patterns (11,12).

While modern low fertility behaviour is likely maladaptive (13,14), we expect that people use decision rules that have been subject to natural selection, and which may maximize reproductive success in other environments. Cultural evolution may also influence fertility decisions in ways that do not presuppose adaptive reproductive behaviour (15).

The Role of Education

Education has long been recognized as a strong predictor of a woman's fertility (16–18). Higher educational achievement is associated with delayed marriage (16) and reduced family size (19,20), although this relationship is not always straightforward. Very early in a transition, small increases in education can actually increase fertility rates in some contexts, but beyond primary school, education is generally associated with declining fertility rates (21). While we know that educational levels are negatively associated with family size in many cultures, we do not know the mechanisms by which this occurs.

Previous research has typically categorised models of fertility decline into economic or 'investment' models, and cultural transmission models. Economic models focus on the individual costs and benefits of producing children and the trade-off between the quantity and quality of children (22–26). This approach focuses on how, in the course of economic development, children tend to become more 'expensive', via increased schooling rates (19), opportunity costs for women (27,28), reduced child mortality rates (29), and changing labour markets (30). Modern labour markets require skills that tend to be acquired in more formal educational settings, forcing parents to invest more to produce quality offspring. Cultural transmission hypotheses instead often focus on whether and how people incorporate the ideas and behaviours of others when making reproductive decisions (6,11,31,32). People may be able to learn about different reproductive strategies through social interactions with their close social network (32,33), from high-status individuals in their communities (who may be viewed as successful and tend to be the first adopters of low-fertility behaviour; (12,34)), or via the diffusion of ideas from further afield, which may be transmitted through mass media (35,36). Most researchers currently agree that both cultural transmission and economic conditions influence reproductive decision-making and that they interact with each other, since cultural changes influence available economic opportunities and changing cultural norms may be initiated by individuals who recognize and respond to the changing costs of reproduction (5,6,33).

In particular, the relationship between education and fertility is likely mediated by both the economic and cultural transmission pathways of fertility decline (5,6,33). Education influences many aspects of a person's life that might lead to reduced fertility. Three broad mechanisms include: a) environmental risk management, b) increases in human capital investment, and c) changes in the cultural traits one is exposed to. These first two mechanisms are generally derived from the economic 'investment' models, while the last mechanism related to changes in cultural traits is usually attributed to cultural transmission hypotheses.

<u>Environmental risk management</u>

Environmental risk management refers to the well-documented empirical finding that a mother's education is inversely related to the likelihood of child mortality (37–40) and reduced child mortality is usually a pre-condition for (or at least a co-condition of) fertility decline. How does education influence child mortality? One obvious route is through improved knowledge of health, allowing women to improve the nutrition and survivorship of their offspring (38,41,42). Education may also allow women to learn about health from other sources outside of a formal school setting, possibly from those in their social network or through media sources (16,43). A third route is through increased household resources or wealth (44,45), making it easier for parents to prevent child mortality in a multitude of ways. Finally, greater education may give women more decision-making power in their households, particularly in relation to decisions about seeking medical help or purchasing medicine for ill children (46). Reduced infant and child mortality are well-known predictors of fertility decline (2). While the mechanisms that produce this relationship are not well understood, evolutionary researchers have argued that when child mortality is extrinsic (e.g. offspring survival is not improved by parents' actions), reduced parental effort and higher fertility will result, whereas when parents gain the ability to reduce child mortality through access to modern medicine, parents will increase per-child investment and lower fertility will result (25,29,47,48). This leads to our first hypothesis (H1), that women's education leads to reduced mortality of children, which in turn, reduces overall fertility.

Human capital

Education increases human capital (49), the skills and knowledge of an individual, which has multi-dimensional effects on a person's life. Human capital changes the market value of a person's work, as people with more embodied capital are of higher monetary value in the labour market. For women (and sometimes men), this presents a time allocation problem, as engaging in the labour market may directly conflict with care of offspring, leading some women to forgo time dedicated to reproduction in favour of more time spent in education or employment, particularly as the opportunity cost of forgoing labour market opportunities increases (27,28). This leads to our second hypothesis (H2), that education increases the ability of a woman to enter the workforce and that either work or gaining an education may directly compete with childbearing activities, leading women to reduce fertility.

Human capital may also change a parent's optimal investment in offspring. The embodied capital theory argues that parents with more human capital invest more in offspring than parents with less human capital because such investment is cheaper for them and thus returns on investment diminish more slowly (25,50). Additionally, human capital becomes one of a number of proxies for status. People may strive to educate themselves and their children to obtain status benefits, including more options on the mating market, or prestigious employment opportunities (which may be another mechanism in H2). Several authors have argued that status motivations trade off with reproduction (51,52), and that education may be one form that this trade-off takes. This leads to our third hypothesis (H3), that a woman's education influences her access to mates (particularly mates of higher quality), which may allow women to marry men with more education (53), leading to reduced fertility in the future (e.g. 5). It is also possible that the role a husband's education plays is not mediated by social status but by couples marrying assortatively, so that women who gain more education are more likely to marry men who are also educated. An increase in husband's education may in turn influence family size preferences, as we tend to see the trade-off between education and fertility even among men (54,55).

Cultural Transmission

Educated women are in privileged social positions, both to learn about 'outside ideas' and to transmit their values to other members of the population (15). Education may not just have effects at the individual level; evidence suggests that there are also effects of education at the community-level, where less educated women may be exposed to low fertility norms and exhibit low fertility outcomes in highly-educated communities (6). Educated women may be more likely to have access to media campaigns promoting smaller families. Their literacy may also give them access to print media such as books, pamphlets, or newspapers which may provide them access to information or influence their reproductive behaviour, or they may be more likely to have access to TV or radio programs that contain either direct or indirect low fertility messages. Education may also improve the reliability of information that women receive, or their ability to evaluate the reliability of information from various sources. It is also possible that education provides women with larger social networks, if they are exposed to more or a more varied group of people by attending school or engaging in the labour market, than they would have if they had less or no education. Larger or more diverse social networks may increase the number and kinds of behaviours and ideas that women are exposed to, making them aware of opportunities they might have missed if their networks were smaller or more homogenous. Convergence on low fertility may then be promoted by homophily in these networks, even in the presence of educational differences between friends (6). This leads to our fourth hypothesis (H4), that women with more education have social networks with lower fertility and that people are similar in their own reproduction to their network partners.

Finally, education provides information about new kinds of contraceptives, which allows people to avoid pregnancy and alter their fertility. This effect may be direct, through courses specifically designed to provide information, or indirect, by improving a woman's ability to gain health knowledge from a source outside of school (16,43). It is also likely that contraceptive information is passed through social networks (56,57). This leads to our fifth hypothesis (H5), that women's education increases knowledge of novel contraceptives, increasing the likelihood of contraceptive use and ultimately leading to a reduction in fertility. While some have argued that individuals inherently want to reduce fertility and modern contraceptives give them the ability to tap into that previously unmet need (58), evolutionary anthropologists generally view contraceptives as a means to an end and want to understand what leads people to want to reduce their fertility initially. If women seek out information about contraceptives because of a desire to reduce fertility, then contraceptive knowledge is self-selected (33). If women learn about contraceptives passively from family planning programs, contraceptive knowledge may not be associated with education (59), however women with more education may still be more likely to choose to use contraceptives to limit fertility.

The Model

Figure 1 displays a hypothesized path model including the different mediators described above. We include an indicator of local mortality (to represent the mortality risk in the environment), work status (of the woman), husband's education, mean fertility of a woman's social network, and the woman's contraceptive knowledge. Husband's education and women's work status will influence household wealth, so we include pathways from husband's education and women's work to household wealth. Finally, all of these variables may have effects on proximate contributors to fertility, like age at first birth (where later ages at first birth are generally associated with lower fertility overall) or contraceptive use (where using contraceptives can reduce the risk of future births). These in turn may influence fertility, which we measure here as a woman's number of live births, the most commonly used measure in the demographic literature. Evolutionary demographers are often also interested in surviving children; we re-ran our analyses using this variable and provide the results in the SM.

Methods

Study Populations: Cross-cultural variation in the role of education

We test our five hypotheses regarding the role of education on fertility decline in three different populations, from three different regions of the world, that are all currently undergoing fertility transitions. This allows us to empirically examine whether our proposed education pathways will be similarly influential in different regions of the world. The three regions we compare are: 1) Matlab, a rural region in Bangladesh, 2) San Borja, a town in Northern Bolivia, and 3) a rural region of Southern Poland. These populations have varying levels of completed fertility, education, child mortality, female labour force participation, and contraceptive knowledge and use. Bangladesh is an unusual case because fertility began to decline quite dramatically in the 1980s even though the country was very poor and had high child mortality (60,61). Some have argued that Bangladesh's fertility decline was the result of highly effective family planning programs (60), though it is unclear if these motivations outweighed the importance of economic change (5). The rural Polish sample, on the other hand, has higher fertility than expected given the country's total fertility rate (TFR), level of wealth, and very low infant mortality rate (6). Bolivia is one of the poorest nations in South America and San Borja, specifically, has higher fertility than both rural Poland and Matlab.

While infant mortality may be a mediator of the relationship between education and fertility, it likely plays a smaller role in contexts where child mortality has already declined to low levels (particularly where it has declined dramatically before we see significant changes in fertility strategy). If almost all children survive infancy, then differences in fertility strategies cannot be a reflection of response to mortality risk. Based on data from San Borja, infant mortality rates have declined from approximately 50 per 1,000 live births before 1990 to 20 per 1,000 live births since 2000. Of course, infant deaths may have been underreported, particularly for deaths that occurred further in the past. Data from all of Bolivia suggests an infant mortality rate of 86 per 1,000 live births in 1990 and a rate of 40 per 1,000 live births in 2008 (62). Infant mortality rates in Matlab, Bangladesh, averaged around 120 children per 1,000 live births through 1978, since which time they have declined by over 75% and in 2010 were between 25 and 35 infant deaths per 1,000 live births (63). In Poland, under-five mortality rates have recently declined from ~21 deaths per 1,000 live births in 1980 to ~5 deaths per 1,000 in 2010 (64). However, infant and neonatal mortality rates are higher than those in other developed EU countries, mostly due to a higher rate of premature births, which are attributed to relatively poorer living and health conditions in Poland (65,66).

All three sites have experienced rapid declines in fertility over the past several decades. In the Matlab area total fertility fell from 6.7 children per woman in 1966 to 2.6 children per woman in 2010 (63). Bolivia has the highest fertility rate in South America; the total fertility rate was approximately 3.3 in 2011, but had fallen from a total fertility rate of 6.6 in 1970 (67). Poland's total fertility rate in 2012 was 1.3, having fallen from a total fertility rate of 3.0 in 1960. Our San Borja and rural Poland samples have higher fertility than the average fertility rate for the country at large. Matlab has higher fertility than urban areas of Bangladesh, but likely has lower fertility than other rural areas. At the time the data were collected, post-reproductive women in our sample had on average 5.1 live births in Matlab, 6.2 in San Borja, and 3.8 in rural Poland.

The Matlab study area includes ~200,000 people on whom detailed demographic data has been collected since 1966 as part of the ICDDR,B Health and Demographic Surveillance System (HDSS) (5). The data used here are from a random sample of 944 women from the Matlab study area on whom Shenk and Towner collected data in 2010; 796 women have all data necessary for this analysis. The San Borja data comes from interviews conducted in 2008 with ~500 women (for additional details, see 33). The rural Poland data was collected in 2009 and 2010 on 1,995 women in 22 communities (for additional details, see 68). Each of these datasets has generally comparable information about a woman's reproductive history, individual characteristics, and community information.

Data Analysis

We use structural equation modelling (SEM) in STATA (v. 13) using the maximum likelihood with missing values method to analyse path models for all three sites (for additional details, see Supplementary Material). Structural equation modelling estimates a series of regression models to obtain direct, indirect and total effects of independent variables on the outcome of interest, total number of live births (69). Additionally, structural equation modelling allows us to compare the relative strengths of mediating variables (as all coefficients presented are standardized). We used the full model and eliminated pathways that indicated poor fit until we had the best fit models. To optimize model fit, we maximized CFI (comparative fit index) and minimized RMSEA (root mean square error of approximation) and BIC (Bayesian information criterion). A good fit of the data is indicated by a CFI greater than 0.95 and RMSEA less than 0.06 (70). SEM cannot establish causality and our results should be interpreted as correlations; however, it does allow us to determine the best

This is an author-produced, peer-reviewed version of this article. The final, definitive version of this document can be found online at *Philosophical Transactions of the Royal Society B: Biological Sciences*, published by the Royal Society. Copyright restrictions may apply. doi: 10.1098/rstb.2015.0156

fit of our hypothesized causal model. To test the robustness of our SEM results, we also conduct Poisson regressions with robust standard errors on number of births including education and mediating factors.

Variable Operationalization

The dependent variable of interest is fertility, measured as the number of live births. We have also included results (in the Supplement) with number of surviving offspring as our dependent variable.

The independent variable is education, which is measured as an ordinal variable on a scale of 1 to 5, which varies slightly by context. This categorization allows us to compare the relative levels of education within a context and to split up the variation that occurs in education across the sites. For details by site, see Supplementary Material.

Our mediating variables include local mortality, women's work, mean fertility of one's social network (measured as both friend network and sibling network) husband's education (same categorisation as women's education), the use and knowledge of contraceptives, and age the age of first birth. We control for household wealth and age throughout the analyses. These are measured in slightly different ways in each site. Please refer to the Supplementary Material for further details.

Results

We present the descriptive statistics for all independent, dependent and control variables in Supplementary Material Table S1. In Figure 2, we present the relationship between education and number of births by age cohort. This figure demonstrates that, as expected, in all three contexts higher levels of education are associated with reduced numbers of live births. This graph also demonstrates that the highest fertility is observed in San Borja, with Matlab and rural Poland having similar fertility across the different age cohorts. Supplementary Material Table S2 provides a summary of results organized by hypothesis.

Hypothesis 1: Women's education leads to reduced mortality of children, which in turn reduces overall fertility.

Figure 3 presents the results of the structural equation model of the potential pathways between education and number of births (for additional details on the results of the SEM model, see Supplementary Material Table S3). The coefficients represent standardised coefficients showing the amount (measured in standard deviations) the particular variable is expected to change as another variable increases by one standard deviation. Across the three sites, there is evidence that a woman's education level is negatively associated with the local mortality of children, but local mortality is only associated with number of births in Matlab and San Borja, where women in areas of high mortality have more births, as expected. In Poland, local mortality is not a strong predictor of fertility or age at first birth and was eliminated from the model. Given that Matlab and San Borja both have relatively high infant mortality rates compared to rural Poland, we expect mortality to play a larger role in predicting fertility. In rural Poland, infant mortality rates are quite low with little variation between families, so fertility does not appear to co-vary with this factor. Table 1 gives the results of the Poisson models for each site, which are consistent with results from the SEM.

Hypothesis 2: Education increases a woman's ability to enter the workforce and that work may directly compete with childbearing activities, leading women to reduce fertility.

Evidence from the SEM suggests that education is a significant predictor of women's working status, where, as predicted, women with more education are more likely to work. In both San Borja and Poland, this work has a significantly positive association with household wealth. In Matlab, this is not the case, possibly because so few women are employed. Except for a few highly educated women, those who do work tend to come from poorer households (and work only when it is necessary). In all three contexts, women who work tend to have later ages at first birth (or possibly women who have later first births are more likely to work, the direction of causality is difficult to determine). While age at first birth tends to be negatively associated with overall fertility, and therefore women's work has an indirect effect on number of births (through its effect on age at first birth), women's work does not have a significant direct effect on number of births in either San Borja or Matlab. In rural Poland, there is a positive effect of women's work on number of births after controlling for the negative effect through age at first birth.

We had anticipated that the direct effect of women's work on fertility might vary by context, since women in Poland and San Borja, but not Matlab, tend to work, but this was not the case. Across all three contexts, education influences the likelihood of working, and work delays the age at first birth, but work only has a direct effect on number of births in Poland, and this was not in the predicted direction. There, women who work have more children. Our Poisson model does not show any significant effect of women's work on number of births in any of the three contexts, and for rural Poland, this difference is probably due to the mediation effects that the SEM can better pick up on (i.e. the different pathways between education, women's work, age at first birth, and number of births). In the Poisson model for Poland, if age at first birth is excluded, women's work has a significant positive effect on number of births, but the effect becomes non-significant with the inclusion of age at first birth.

<u>Hypothesis 3: Women's education is correlated with husband's education, and increases in husband's education reduce fertility.</u>

Across all three contexts, women's education is significantly correlated with husband's education. Husband's education also predicts number of births in rural Poland and Matlab, with men with high levels of education tending to have wives with fewer births, but there is no effect in San Borja after controlling for the respondent's education and the effect through wealth. This result is replicated in the Poisson regression model in Table 1. This suggests that in San Borja women's education plays a larger role in predicting the number births than husband's education does, and any effect of husband's education is mediated through household wealth.

<u>Hypothesis 4: Women with more education have social networks with lower fertility and people are similar in their own reproduction to their network partners.</u>

We measured social networks as both a woman's friend network (or her local community in Matlab) and her sibling set. Across all three sites, women with more education have friends and siblings with lower fertility. Friends' and siblings' fertility significantly predicts number of births in Matlab and Poland, where having social networks with higher fertility is positively associated with own reproduction. Interestingly, social network fertility is not a significant predictor of own fertility in San Borja (the best-fitting model does include friends' fertility, but the p-value > 0.10). The Poisson regression provides consistent results, where both friends' fertility and sibling fertility have positive effects on total number of births for Matlab and Poland, but in San Borja, only friends' fertility has a significant effect.

<u>Hypothesis 5: Women's education increases women's knowledge of novel contraceptives, increasing the likelihood of contraceptive use and ultimately leading to a reduction in fertility.</u>

The knowledge of contraceptives was only recorded in San Borja and Poland. In both contexts, women with higher levels of education learned about contraceptives earlier in life. In Matlab, where all women of the same age have equal access to contraceptive knowledge, education is associated with an increased likelihood of contraceptive use. Additionally, in San Borja and Poland learning about contraceptives earlier in life is associated with earlier adoption of contraceptives. These results are all as expected. However, in both San Borja and Poland, where we have data on age at first contraceptive use, an earlier age at contraceptive use is correlated with an earlier age at first birth. In Matlab, women who adopt contraceptives also have an earlier age at first birth. These results may seem counter-intuitive, but may indicate that women in these contexts usually use contraceptives responsively to space births and/or stop reproducing. Nonetheless, in both Poland and

San Borja, earlier ages of contraceptive adoption are associated with fewer numbers of births. In contrast, in Matlab using contraceptives is associated with higher fertility.

In the Poisson models, we compare those women who *ever* used contraceptives with those who did not across the three sites. Any contraceptive use is not associated with number of births in rural Poland (but see 32), but in both San Borja and Matlab using contraceptives is associated with more births. While researchers studying developed nations with wage-labour economies often expect contraceptive use to delay or reduce births, in higher-fertility contexts it is likely that women who have attained their desired family size are more likely to use contraceptives to stop reproducing, or indeed, to achieve higher fertility (71).

Discussion

As predicted, local mortality is a mediator of the relationship between education and fertility, and was most important in Matlab and San Borja, where infant mortality is higher and more varied than in Poland. This suggests that mortality rates can influence fertility when both are declining simultaneously; where mortality has declined before we see fertility change, mortality may have little impact on individual-level fertility. We measured local mortality slightly differently in each context, which makes it hard to know if these differences are the result of true effects or differences in our measurements. Nonetheless, in those contexts with higher mortality there appears to be a greater effect on the relationship between education and fertility than in those contexts with lower mortality. The reverse is also possible; reductions in child mortality may lead to increased education rates.

Women’s work mediates education and reduced fertility relatively consistently across contexts, though not in the way we predicted. Work was not associated with total number of births in San Borja and Matlab, and was positively associated with births in rural Poland, but work did delay age at first birth, indirectly impacting overall fertility. In Poland, work status indicates whether a woman ever worked; in Matlab it indicates either currently working or working before retirement. It is therefore hard to know if work status predicts age at first birth or the other way around. In San Borja, work status is measured at the time of first birth, so is more likely to have a direct impact on first birth. Other measures of work status in San Borja, like the percentage of a woman’s reproductive span that she worked, were not better predictors of number of births or timing of first birth (results not shown).

It is surprising that women’s work does not have a direct negative effect on fertility across these sites even though it is an important predictor of fertility in many settings (for example 27,28,72,73). It is likely that in these transitioning contexts, women's work has been integrated into their childcare responsibilities and/or women have access to much more significant levels of allocare from kin than is true in long-industrialized societies or urban areas. Women in Matlab, Bangladesh, for example, usually live in *baris* with several patrilocal households and may also live close to their natal kin (e.g. 74). In San Borja, approximately 91% of women either do not engage in the labour market or can combine employment with childcare, by, for example, working at home or running a store (33). In Poland, women frequently combine farm and off-farm work (75), and live close to their kin. In some regions of the world, like rural Bangladesh, women rarely work outside the home (only 5% of women in the Matlab sample reported ever working in the wage labour market). In these cases, there are few opportunity costs of women’s work to constrain reproduction, though education may provide women with payoffs on the mating market instead of the labour market.

Husband’s education mediated education and fertility in rural Poland and Matlab, where a woman’s education is correlated with her husband’s education, which in turn has a negative effect on the number of births. In San Borja, a woman and her husband’s education are highly correlated, but after controlling for the woman’s education, husband’s education does not predict number of births. Husband’s education may have a smaller influence on fertility in San Borja because of higher divorce rates (approximately 33% of marriages end in divorce 76), while divorce rates in Matlab and Poland are much lower (63). By examining fertility outcomes for an individual woman, her current husband’s education may not correspond to her lifetime fertility decisions if their relationship has not extended throughout her reproductive career, which may influence our San Borja results more than the other contexts.

We might expect that education influences household wealth as well, which in turn may affect fertility. As recent work has demonstrated, wealth and status may be measured in many different ways, each having a different effect on fertility (5,68,77,78). In rural Poland, there appears to be an opposite effect of material wealth and husband's education, where greater wealth reduces age at first birth and increases fertility, while increased levels of husband's education reduces fertility. This is one of the benefits of using structural equation modelling, to detangle these differing effects (see also 68 where multiple measures of wealth and status, as well as interactions between them, are examined). The results from Poland support the theoretical predictions from Kaplan and Lancaster's embodied capital model, where education reduces fertility as parents invest more in each offspring, but controlling for education, wealth has a positive effect on the overall budget of investments resulting in increased fertility (50). Colleran and colleagues also show that these two different factors interact, and so should not be interpreted in isolation (68). In San Borja, greater household wealth is associated with later ages at first birth and fewer births, exactly the opposite of what we see in rural Poland. In Matlab, the two measures of wealth have differing effects. If the household owns land, there is an association with earlier age at first birth and higher fertility, but household income has only a marginally significant negative effect on age at first birth and no significant effect on fertility. This is consistent with previous findings that different types of wealth can vary in their effects on fertility, and especially that farming wealth is often associated with higher fertility (e.g. 5,75).

We found the most consistent support for the idea that one's social network is influenced by one's level of education, which in turn influences one's number of births. Both friends' fertility and siblings' fertility are indicators of overall fertility in rural Poland and Matlab. In San Borja, friends' fertility tends to be associated with number of offspring, while siblings' fertility is not. Sibling fertility may be confounded by culturally and genetically heritable aspects of fertility behaviour, along with ecological similarity, whereas non-kin friend networks are only confounded by ecological similarity (although, in rural Poland, almost half of all network partners were not residence in the same community as ego (6)). Non-kin networks may therefore provide better evidence for the influence of one's social network on fertility. In all three sites, friends' fertility has a similar or larger effect size than siblings' fertility, suggesting that social networks play an important role in fertility transition. It is possible that people seek out friends with similar fertility to their own, resulting in a reverse causation problem, but evidence suggests this is not the case. In rural Poland, friendships usually began well before reproduction took place, with mean network durations of 23 years (6). In Matlab, the social network actually measures the fertility of the entire *bari*, or patrilineal neighbourhood, making reverse causation much less of a problem. Unfortunately, the interpretation of this variable is ambiguous, as the relationships we observe between social networks and fertility may be mediated by either social influence or by shared ecology. Our analyses do not allow us to differentiate between these two mechanisms, but future work may allow the relationship to be unpacked.

By comparing the different measures of contraceptive use we can observe that how contraceptives are operationalized likely influences inferences about their effect on fertility (32). In San Borja and rural Poland, where we used age at contraceptive uptake, a later age at adoption of contraception is associated with higher fertility. In Matlab, we operationalized this as 'ever using contraceptives', and found a positive correlation with fertility; where women used contraceptives, they had higher fertility (this effect was replicated in San Borja in the Poisson model). This seems counter-intuitive, but as demonstrated by other researchers, in contexts of early fertility transition, many women use contraceptives to either space or end their reproductive career once they have achieved desired family size and in fact, women who were ever-users of contraception often ended up with higher completed fertility (34,79,80). Use of contraceptives may thus indicate women who already have many children and/or have higher parity for age and would like to prevent future births. This indicates that knowing the timing of contraceptive uptake (or duration of its use) is an important determinant of whether contraceptives will be associated with higher or lower fertility.

In rural Poland, using any contraceptives (as modelled in the Poisson model) is not associated with number of births. This may be because women of all ages are included here, and there are cohort differences in both the methods being used by older and younger women, and the changing reproductive preferences that the cross-section captures. For example, women in the youngest cohort (under age 30), have lower fertility if they have ever used contraceptives, while women in an older cohort (30-39), have higher fertility if they have ever used contraceptives, and post-reproductive women have fewer children again. We operationalized contraceptive use to include both ‘modern’ and ‘traditional’ methods in rural Poland, but we might expect education to differentially influence knowledge about novel/modern versus traditional contraceptives, influencing their subsequent use. If we restrict our analysis to modern contraceptive use, we still find that education influences age at contraceptive knowledge which in turn mediates age at use of novel contraceptives. However, the pathways to reproductive outcomes now differ: age at modern contraceptive use much more strongly mediates number of births (the effect size is doubled), and more weakly mediates age at first birth (the effect size is halved). This suggests that while education has a comparable effect on the age women are learning about and using different kinds of contraceptives, the age at which modern methods are first used has a larger effect on reducing births. Different operationalizations of contraceptive methods are affected by different predictors in this population (32), which further highlights the fact that contraceptives are used and diffused in a variety of ways, depending on the context.

Finally, given that the Matlab region has a very effective family planning program, where almost all women are taught about contraceptives, the level of knowledge likely has little effect on fertility outcomes. This might have been an important variable at the beginning of the family planning program initiative, but once the community is saturated with knowledge and access, fertility differences are not likely driven by contraceptive knowledge but instead by individual strategies and decisions regarding fertility. This clearly shows how the diffusion of information is not equivalent to the diffusion of behaviour (32,81) .

We should note that while contraceptive use is itself a proximate mechanism of fertility decline, its diffusion is a useful proxy for the decision-mechanisms that underlie its adoption. It is also debated whether access to new methods is a purely exogenous factor in fertility transitions. Governments tend to initiate family planning programs non-randomly and may tailor their program to areas where people have high numbers of offspring and may be interested in learning ways to reduce their fertility (82,83). Women who want to reduce their fertility may be more likely to seek out information on contraceptives, making the effect of contraceptives endogenous (for alternative interpretations of information seeking and social contagion, see 32,84). Understanding the links between contraceptive knowledge and use may help us understand what predicts who learns (or is taught) about contraceptives. In the end though, it is the motivation to reduce fertility, not the means by which it is achieved, that is of theoretical interest to most evolutionary anthropologists.

There is evidence from our analyses that the effect of education on fertility is likely mediated by several different factors, including local mortality rates (where mortality varies), husband’s education, wealth, contraceptive use, and the mean fertility of a woman’s social network. But even after controlling for these potential pathways, education has an additional direct effect on fertility in rural Poland and San Borja, suggesting that education matters beyond the covariates included here. For example, community-level education has been shown to matter over and above individual education in the Polish context (6). This may be driven by higher rates of horizontal relative to vertical cultural transmission (see 15) in communities with higher average education, or by unobserved characteristics of particular contexts that jointly determine higher education and lower fertility. Education also has a significant direct effect on age at first birth, where women with more education tend to have later ages at first birth in all three contexts. This may be partially explained by women remaining in school and tending to delay family formation while they are completing their education, but in San Borja and Matlab where women rarely achieve higher education, education may delay reproduction for reasons other than simply the conflict between going to school and starting a family. In Matlab, for example, women with more education are able to marry higher-status grooms and it may take time to find and negotiate such matches.

Conclusions

This paper highlights the great importance of comparative work in unpacking the dynamics of fertility decline cross-culturally. We see several similarities across three very distinct field sites on three continents, suggesting that common elements are important in the demographic transition cross-culturally, and especially in the way that fertility decline is mediated by education. Yet we also see distinctions between field sites, suggesting that local ecologies play a tangible role in the impact of education and how fertility decline unfolds.

Taken together, these findings corroborate suggestions (5,16,17,33) that education is such a powerful cross-cultural predictor of fertility decline because it operates through multiple pathways. It also has effects at multiple levels of analysis (6). While not every pathway may be important in every ecological context, more than one pathway is likely to matter in most cultures, leading to strong cross-cultural effects of women's education on fertility despite variation in local circumstances. More broadly, these results reinforce the idea that the demographic transition is both a global and a local phenomenon—with a number of potential causal pathways that may act across many societies, despite the fact that only some of them may be active in any particular society. Finally, our results suggest that a combination of both economic and cultural transmission models are needed to explain fertility decline.

Additional Information

Acknowledgments

We would like to thank all the women who took part in the studies as well as our local field assistants. From Matlab, we would like to thank the International Centre for Diarrhoeal Disease Research, Bangladesh, ICDDR,B staff (especially Taslim Ali, Md. Emdad, and Ali Ahmed), and field assistants (Shifat Khan, Nargis Sultana, Latifun Nahar, Akterun Naher, Lutfa Begum, Mouloda Aziz, Farhana Akand, and Sumaiya Shifat). From Poland, we would like to thank Grazyna Jasienska, Andrzej Galbarczyk and Ilona Nenko, as well as all field assistants, the Wojtas and Markiewicz families, and the parish Rectors who helped publicize the study. From San Borja, we would like to thank Josue Otero and local field assistants for help collecting data. We thank Rebecca Sear and two anonymous reviewers for helpful comments on earlier manuscript drafts.

Funding Statement

This research was funded by National Science Foundation (award no. BCS-0924630), a Research Leave from the University of Missouri, the UK Economic and Social Research Council, the Wenner Gren Foundation for Anthropological Research and Osmundsen Initiative (Disseration Fieldwork grant no. 8182), UCL Graduate School, the Gay Clifford Fund, ANR-Labex IAST, the University of New Mexico Graduate and Professional Student Association and the University of New Mexico Office of Graduate Studies.

Data Accessibility

Please contact the authors for the data. KS has San Borja data, MT and MS have Matlab data, and HC has rural Poland data.

Competing Interests

We have no competing interests.

Authors' Contributions

All authors (KS, MT, MS, HC) made substantial contributions to conception and design, acquisition of data, analysis and interpretation of data; revised the article critically for important intellectual content; and gave final approval of the version to be published. KS drafted the article and performed the majority of analyses.

This is an author-produced, peer-reviewed version of this article. The final, definitive version of this document can be found online at *Philosophical Transactions of the Royal Society B: Biological Sciences*, published by the Royal Society. Copyright restrictions may apply. doi: 10.1098/rstb.2015.0156

Reference

1. Davis K. 1945. The World Demographic Transition. *Ann Am Acad Policital Soc Sci.* **237**, 1–11.
2. Mason KO. 1997. Explaining fertility transitions. *Demography.* **34**, 443–54.
3. Chesnais JC. 1992. Demographic Transition: stages, patterns, and economic implications: a longitudinal study of sixty-seven countries covering the period 1720-1984. Oxford: Clarendon Press;
4. Borgerhoff Mulder M. 1998. The demographic transition: Are we any closer to an evolutionary explanation? *Trends Ecol Evol.* **13**, 266–70.
5. Shenk MK, Towner MC, Kress HC, Alam N. 2013. A model comparison approach shows stronger support for economic models of fertility decline. *Proc Natl Acad Sci.* **110**, 8045–50.
6. Colleran H, Jasienska G, Nenko I, Galbarczyk A, Mace R. 2014. Community-level education accelerates the cultural evolution of fertility decline. *Proc R Soc B.* **281**, 20132732.
7. Low B. 2000. Sex, wealth, and fertility: Old rules, new environments. In: Cronk L, Chagnon N, Irons W, editors. *Adaptation and Human Behavior: An Anthropological Perspective.* Hawthrone, Ny: Aldine de Gruyter; p. 323–44.
8. Hill K, Kaplan H. 1999. Life History Traits in Humans: Theory and Empirical Studies. *Annu Rev Anthropol.* **28**, 397–430.
9. Roff DA. 1992. The Evolution of Life Histories. Theory and Analysis. New Yrok: Chapman & Hall;
10. Stearns SC. 1992. The evolution of life histories. Oxford: Oxford University Press;
11. Boyd R, Richerson P. 1985. Culture and the evolutionary process. Chicago: University of Chicago Press; 331 p.
12. Richerson PJ, Boyd R. 2005. Not by genes alone: How culture transformed human evolution. Chicago: Chicago University Press;
13. Kaplan H, Lancaster JB, Bock JA, Johnson SE. 1995. Does Observed Fertility Maximize Fitness Among New Mexican Men? A Test of an Optimality Model and a New Theory of Parental Investment in the Embodied Capital of Offpspring. *Hum Nat.* **6**, 325–60.
14. Goodman A, Koupil I, Lawson DW. 2012 [cited 2012 Oct 30]. Low fertility increases descendant socioeconomic position but reduces long-term fitness in a modern post-industrial society. *Proc R Soc B [Internet].* **279**, 4342–51. Available from: http://www.ncbi.nlm.nih.gov/pubmed/22933371
15. Colleran H. The cultural evolution of fertility decline. *Philos Trans R Soc B-Biological Sci.*
16. Castro Martin T, Juarez F. 1995. The Impact of Women's Education on Fertility In Latin America: Searching for Explanations. *Int Fam Plan Perspect.* **21**, 52–7.
17. Basu AM. 2002. Why does education lead to lower fertility? A critical review of some of the possibilities. *World Dev.* **30**, 1779–90.
18. Lutz W, Samir K. 2011. Global Human Capital: Integrating Education and Population. *Science.* **333**, 587–92.
19. Caldwell JC. 1980. Mass Education as a Determinant of the Timing of Fertility Decline. *Popul Dev Rev.* **6**, 225–55.
20. Zurack HC. 1977. The effect of education of women and urbanization on actual and desired fertility and on fertility control in Lebanon. *Popul Bull United Nations Econ Comm West Asia.* **13**, 32–41.
21. Singh S, Casterline J. 1985. The socio-economic determinants of fertility. In: Cleland J, Hobcroft J, editors. *Reproductive change in developing countries: insights from the World Fertility Survey.* London: Oxford University Press; p. 199–222.
22. Becker G, Lewis HG. 1973. On the interaction between the quantity and quality of children. *J Polit Econ.* **81**, S279–88.
23. Kaplan H, Lancaster JB, Tucker WT, Anderson KG. 2002. Evolutionary approach to below replacement fertility. *Am J Hum Biol.* **14**, 233–56.
24. Caldwell JC. 1976. Toward A Restatement of Demographic Transition Theory. *Popul Dev Rev.* **2**, 321.
25. Kaplan H. 1996. A Theory of Fertility and Parental Investment in Traditional and Modern Human Societies. *Yearb Phys Anthropol.* **39**, 91–135.
26. Low BS, Simon CP, Anderson KG. 2002. An evolutionary ecological perspective on demographic transitions: Modeling multiple currencies. *Am J Hum Biol.* **14**, 149–67.
27. Ermisch J. 1988. Economic Influences on Birth Rates. *Natl Inst Econ Rev.* **126**, 71–81.
28. Hoem B, Hoem JM. 1989. The Impact of Women's Employment on Second and Third Births in Modern Sweden. *Popul Stud (NY).* **43**, 47–67.

29. Quinlan RJ. 2007. Human parental effort and environmental risk. *Proc Biol Sci.* **274**, 121–5.

30. Kaplan H, Lancaster J. 2002. The Evolutionary Economics and Psychology of the Demographic Transition to Low Fertility. In: Cronk L, Chagnon N, Irons W, editors. *Adaptation and Human Behavior: An Anthropological Perspective.* Hawthorne, NY: Aldine de Gruyter; p. 283–322.

31. Cleland J, Wilson C. 1987. Demand Theories of the Fertility Transition: An Iconoclastic View. *Popul Stud (NY).* **41**, 5–30.

32. Colleran H, Mace R. 2015. Social network- and community-level influences on contraceptive use: evidence from rural Poland. *Proc R Soc B Biol Sci.* **282**, 20150398–20150398.

33. Snopkowski K, Kaplan H. 2014. A synthetic biosocial model of fertility transition: Testing the relative contribution of embodied capital theory, changing cultural norms, and women's labor force participation. *Am J Phys Anthropol.* **154**, 322–33.

34. Alvergne A, Gibson MA, Gurmu E, Mace R. 2011. Social transmission and the spread of modern contraception in rural Ethiopia. *PLoS One.* **6**, e22515.

35. Faria VE, Potter JE. 1999. Television, Telenovelas, and Fertility Change in Northeast Brazil. In: Leete R, editor. *Dynamics of Values in Fertility Change.* Oxford, England: Oxford University Press; p. 252–72.

36. Rogers EM, Vaughan PW, Swalehe RM a, Rao N, Svenkerud P, Sood S. 1999. Effects Family Radio Opera Soap in Tanzania Planning Behavior of. *Stud Fam Plann.* **30**, 193–211.

37. Fuchs R, Pamuk E, Lutz W. 2010. Education or wealth: which matters more for reducing child mortality in developing countries? *Vienna Yearb Popul Res.* **8**, 175–99.

38. Glewwe P. 1999. Why Does Mother's Schooling Raise Child Health in Developing Countries? Evidence from Morocco. *J Hum Resour.* **34**, 124–59.

39. Caldwell JC. 1979. Education as a factor in mortality decline an examination of Nigerian data. *Popul Stud (NY).* **33**, 395–413.

40. Peña R, Wall S, Persson LÅ. 2000. The effect of poverty, social inequity, and maternal education on infant mortality in Nicaragua, 1988-1993. *Am J Public Health.* **90**, 64–9.

41. Caldwell J, McDonald P. 1982. Influence of maternal education on infant and child mortality: Levels and causes. *Health Policy Educ.* **2**, 251–67.

42. Heaton TB, Forste R, Hoffmann JP, Flake D. 2005. Cross-national variation in family influences on child health. *Soc Sci Med.* **60**, 97–108.

43. Stuebing KW. 1997. Maternal schooling and comprehension of child health information in urban Zambia: is literacy a missing link in the maternal schooling-child health relationship? *Health Transit Rev.* **7**, 151–71.

44. Bicego GT, Boerma JT. 1993. Maternal education and child survival: A comparative study of survey data from 17 countries. *Soc Sci Med.* **36**, 1207–27.

45. Hobcraft JN, McDonald JW, Rutstein SO. 1984. Socio-Economic Factors in Infant and Child Mortality: A Cross-national Comparison. *Popul Stud (NY).* **38**, 193–223.

46. Becker S, Fonseca-Becker F, Schenck-Yglesias C. 2006. Husbands' and wives' reports of women's decision-making power in Western Guatemala and their effects on preventive health behaviors. *Soc Sci Med.* **62**, 2313–26.

47. Leslie P, Winterhalder B. 2002. Demographic consequences of unpredictability in fertility outcomes. *Am J Hum Biol.* **14**, 168–83.

48. Chisholm JS. 1993. Death, Hope, and Sex: Life-History Theory and the Development of Reproductive Strategies. *Curr Anthropol.* **34**, 1.

49. Becker G. 1975. Human Capital: A theoretical and empirical analysis, with special reference to educaiton. Chicago: University of Chicago Press;

50. Kaplan HS, Lancaster JB. 2000. The Evolutionary Economics and Psychology of the Demographic Transition to Low Fertility. In: Cronk L, Chagnon N, Irons W, editors. *Adaptation and Human Behavior: An Anthropological Perspective.* New York: Aldine de Gruyter; p. 283–322.

51. Boone JL, Kessler K. 1999. More Status or More Children: Social Status, Fertility Reduction, and Long-term Fitness. *Evol Hum Behav.* **20**, 257–77.

52. Shenk M, Kaplan H, Hooper P. Status competition, inequality, and fertility: Implications for the demographic transition. *Philos Trans R Soc B-Biological Sci.*

53. Becker G. 1973. A Theory of Marriage: Part I. *J Polit Econ.* **81**, 813–46.

54. Cleland J, Rodriguez G. 1988. The Effect of Parental Education on Marital Fertility in Developing Countries. *Popul Stud (NY).* **42**, 419–42.

55. DeRose LF, Ezeh AC. 2005. Men's influence on the onset and progress of fertility decline in Ghana, 1988-98. *Popul Stud (NY).* **59**, 197–210.

56. Gayen K, Raeside R. 2010. Social networks and contraception practice of women in rural Bangladesh. *Soc Sci Med.* Elsevier Ltd; **71**, 1584–92.

57. Lindstrom DP, Mufioz-franco E. 2005. Migration and the Diffusion of Modern Contraceptive Knowledge and Use in Rural Guatemala. *Stud Fam Plann.* **36**, 277–88.

58. Lopreato J, Yu M. 1988. Human Fertility and Fitness Optimization. *Ethol Sociobiol.* **9**, 269–89.

59. McNay K, Arokiasamy P, Cassen R. 2003. Why are uneducated women in India using contraception? A multilevel analysis. *Popul Stud (NY).* **57**, 21–40.

60. Cleland JG. 1994. The determinants of reproductive change in Bangladesh: success in a challenging environment. *World Bank regional and sectoral studies.* xii, 187 p.

61. Caldwell JC, Barkat-E-Khuda, Caldwell B, Pieris I, Caldwell P. 1999. The Bangladesh fertility decline: an interpretation. *Popul Dev Rev.* **25**, 67–84.

62. The World Bank. 2015 [cited 2015 Jan 1]. Mortality rate, infant (per 1,000 live births) [Internet]. Available from: http://data.worldbank.org/indicator/SP.DYN.IMRT.IN?page=1

63. ICDDR B. 2012. Health and Demographic Surveillance System - Matlab, v.44. Registration of healht and demographic events, 2010, Scientific Report No. 117. Dhaka;

64. United Nations Statistics Division. 2015 [cited 2015 Oct 23]. Poland [Internet]. Available from: http://unstats.un.org/unsd/pocketbook/PDF/2013/Poland.pdf

65. Golinowska S, Sowa A. 2006. Health and Morbidity in the Accession Countries Country Report - Poland.

66. Szamotulska K. 2010. Health status of mothers and children in Poland compared to other European Union countries on the basis of EURO-PERISTAT indicators. *Med Wieku Rozwoj.* **14**, 113.

67. United Nations Statistics Division. 2014. UN data: A world of information [Internet]. Available from: http://data.un.org/Data.aspx?d=SOWC&f=inID:127

68. Colleran H, Jasienska G, Nenko I, Galbarczyk A, Mace R. 2015. Fertility decline and the changing dynamics of wealth, status and inequality. *Proc R Soc B Biol Sci.* **282**, 20150287.

69. Kline RB. 2005. Principles and practice of structural equation modeling 2nd ed. New York: Guilford Press;

70. Hu L, Bentler PM. 1999. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Struct Equ Model A Multidiscip J.* **6**, 1–55.

71. Bledsoe CH, Hill AG, D'Alessandro U, Langerock P. 1994. Constructing Natural Fertility: The Use of Western Contraceptive Technologies in Rural Gambia. *Popul Dev Rev.* **20**, 81–113.

72. Greenwood MJ. 2009. A note on the changing relationship between fertiltiy and female employment rates in developed countries. *J Popul Econ.* **15**, 2009–2009.

73. Willis RJ. 1973. A New Approach to the Economic Theory of Fertility Behavior. *J Polit Econ.* **81**, S14–64.

74. Fraser Schoen R. 2014. The social complexity of woman and child valuation in rural Bangladesh. University of Missouri;

75. Colleran H. 2014. Farming in transition: land and property inheritance in a rural Polish population. *Soc Biol Hum Aff.* **78**, 7–19.

76. Snopkowski K. Marital Dissolution and Child Educational Outcomes in San Borja, Bolivia. *Hum Nat.*

77. Shenk MK. 2004. Embodied Capital and Heritable Wealth in Complex Cultures: A Class-Based Analysis of Parental Investment in Urban South India. *Res Econ Anthropol.* **23**, 307–33.

78. Hopcroft RL. 2006. Sex, status, and reproductive success in the contemporary United States. *Evol Hum Behav.* **27**, 104–20.

79. Mace R, Colleran H. 2009. Kin influence on the decision to start using modern contraception: A longitudinal study from rural Gambia. *Am J Hum Biol.* **21**, 472–7.

80. Alvergne A, Lawson DW, Clarke PMR, Gurmu E, Mace R. 2013. Fertility, parental investment, and the early adoption of modern contraception in rural Ethiopia. *Am J Hum Biol.* **25**, 107–15.

81. Khan S, Mishra V, Arnold F, Abderrahim N. 2007. Contraceptive trends in developing countries [Internet]. Available from: http://dhsprogram.com/pubs/pdf/CR16/CR16.pdf

82. Molyneaux JW, Gertler PJ. 2000. The Impact of Targeted Family Planning Programs in Indonesia. *Popul Dev Rev.* **26**, 61–85.

83. Gertler PJ, Molyneaux JW. 1994. How Economic Development and Family Planning Programs Combined to Reduce Indonesian Fertility. *Demography.* **31**, 33–63.

84. Behrman JR, Kohler H-P, Watkins SC. 2002. Social networks and changes in contraceptive use over time: evidence from a longitudinal study in rural Kenya. *Demography.* **39**, 713–38.

Tables

Table 1

	Poland			San Borja			Matlab		
	Coef.	SE	p-value	Coef.	SE	p-value	Coef.	SE	p-value
Contraceptive Use (ref = never used)									
Used Contraceptives	0.019	0.036	0.595	0.097	0.052	0.064	**0.129**	**0.062**	**0.037**
Unknown contraceptive use	0.252	0.159	0.113				-0.114	0.079	0.146
Sibling fertility	**0.031**	**0.012**	**0.010**	0.026	0.019	0.155	**0.033**	**0.013**	**0.009**
Friends' fertility	**0.033**	**0.012**	**0.005**	**0.038**	**0.017**	**0.029**	**0.124**	**0.021**	**<0.001**
Women's work	0.049	0.044	0.270	0.027	0.067	0.683	-0.083	0.063	0.184
Child mortality	-1.155	0.854	0.177	**0.659**	**0.246**	**0.007**	**0.026**	**0.007**	**<0.001**
Wealth	**0.048**	**0.015**	**0.002**	**-0.077**	**0.028**	**0.006**			
Income (log)							0.012	0.015	0.447
Owns Land							0.066	0.042	0.115
Husband's education (ref = lowest level)									
2	-0.123	0.101	0.223	-0.190	0.241	0.431	0.003	0.037	0.930
3	-0.205	0.106	0.053	-0.171	0.246	0.487	**-0.092**	**0.041**	**0.026**
4	**-0.299**	**0.109**	**0.006**	-0.237	0.242	0.327	**-0.136**	**0.066**	**0.040**
5	**-0.307**	**0.122**	**0.012**	-0.386	0.262	0.141	-0.177	0.106	0.095
Women's education (ref = lowest level)									
2	0.082	0.099	0.409	-0.006	0.074	0.931	0.043	0.034	0.197
3	0.123	0.105	0.243	**-0.152**	**0.068**	**0.025**	0.014	0.051	0.790
4	0.015	0.108	0.890	**-0.178**	**0.089**	**0.045**	-0.259	0.153	0.092
5	-0.110	0.113	0.329	-0.139	0.148	0.349	-0.002	0.186	0.992
Age at first birth	**-0.037**	**0.004**	**<0.001**	**-0.039**	**0.008**	**<0.001**	**-0.022**	**0.009**	**0.013**
Age	**0.013**	**0.001**	**<0.001**	**0.024**	**0.003**	**<0.001**	**0.022**	**0.002**	**<0.001**
Constant	**1.324**	**0.176**	**<0.001**	**1.173**	**0.255**	**<0.001**	-0.047	0.317	0.882
n		1337			285			577	

Note: SE represents standard error. **Bold** values represent p<0.05.

Figure and table captions

Figure 1: Hypothesized path model of the effects of education on number of births

Figure 2: The effect of education on number of births (controlling for age category) in Matlab, San Borja, and Poland. Education categories range from 1 to 5. In Matlab and San Borja, 1 = no education, 2 = low primary education, 3 = high primary/low secondary education, 4 = completed secondary school, 5=tertiary education. In Poland, 1= some primary, 2=full primary, 3=vocational, 4 = secondary, 5=tertiary. Error bars represent standard errors.

Figure 3: Structural equation model of the pathways between education and fertility in a) rural Poland, b) San Borja, and c) Matlab. All models include age as a control (not shown, see Supplementary Material Table 3). ^ p < 0.10, * p < 0.05, ** p <0.01, *** p < 0.001.

Table 1: Poisson regression analyses predicting total live births in Poland, San Borja, and Matlab

Tables

Table 1

	Poland			San Borja			Matlab		
	Coef.	SE	p-value	Coef.	SE	p-value	Coef.	SE	p-value
Contraceptive Use (ref = never used)									
Used Contraceptives	0.019	0.036	0.595	0.097	0.052	0.064	**0.129**	**0.062**	**0.037**
Unknown contraceptive use	0.252	0.159	0.113				-0.114	0.079	0.146
Sibling fertility	**0.031**	**0.012**	**0.010**	0.026	0.019	0.155	**0.033**	**0.013**	**0.009**
Friends' fertility	**0.033**	**0.012**	**0.005**	**0.038**	**0.017**	**0.029**	**0.124**	**0.021**	**<0.001**
Women's work	0.049	0.044	0.270	0.027	0.067	0.683	-0.083	0.063	0.184
Child mortality	-1.155	0.854	0.177	**0.659**	**0.246**	**0.007**	**0.026**	**0.007**	**<0.001**
Wealth	**0.048**	**0.015**	**0.002**	**-0.077**	**0.028**	**0.006**			
Income (log)							0.012	0.015	0.447
Owns Land							0.066	0.042	0.115
Husband's education (ref = lowest level)									
2	-0.123	0.101	0.223	-0.190	0.241	0.431	0.003	0.037	0.930
3	-0.205	0.106	0.053	-0.171	0.246	0.487	**-0.092**	**0.041**	**0.026**
4	**-0.299**	**0.109**	**0.006**	-0.237	0.242	0.327	**-0.136**	**0.066**	**0.040**
5	**-0.307**	**0.122**	**0.012**	-0.386	0.262	0.141	-0.177	0.106	0.095
Women's education (ref = lowest level)									
2	0.082	0.099	0.409	-0.006	0.074	0.931	0.043	0.034	0.197
3	0.123	0.105	0.243	**-0.152**	**0.068**	**0.025**	0.014	0.051	0.790
4	0.015	0.108	0.890	**-0.178**	**0.089**	**0.045**	-0.259	0.153	0.092
5	-0.110	0.113	0.329	-0.139	0.148	0.349	-0.002	0.186	0.992
Age at first birth	**-0.037**	**0.004**	**<0.001**	**-0.039**	**0.008**	**<0.001**	**-0.022**	**0.009**	**0.013**
Age	**0.013**	**0.001**	**<0.001**	**0.024**	**0.003**	**<0.001**	**0.022**	**0.002**	**<0.001**
Constant	**1.324**	**0.176**	**<0.001**	**1.173**	**0.255**	**<0.001**	-0.047	0.317	0.882
n		1337			285			577	

Note: SE represents standard error. **Bold** values represent p<0.05.

Figure and table captions

Figure 1: Hypothesized path model of the effects of education on number of births

Figure 2: The effect of education on number of births (controlling for age category) in Matlab, San Borja, and Poland. Education categories range from 1 to 5. In Matlab and San Borja, 1 = no education, 2 = low primary education, 3 = high primary/low secondary education, 4 = completed secondary school, 5=tertiary education. In Poland, 1= some primary, 2=full primary, 3=vocational, 4 = secondary, 5=tertiary. Error bars represent standard errors.

Figure 3: Structural equation model of the pathways between education and fertility in a) rural Poland, b) San Borja, and c) Matlab. All models include age as a control (not shown, see Supplementary Material Table 3). ^ p < 0.10, * p < 0.05, ** p <0.01, *** p < 0.001.

Table 1: Poisson regression analyses predicting total live births in Poland, San Borja, and Matlab